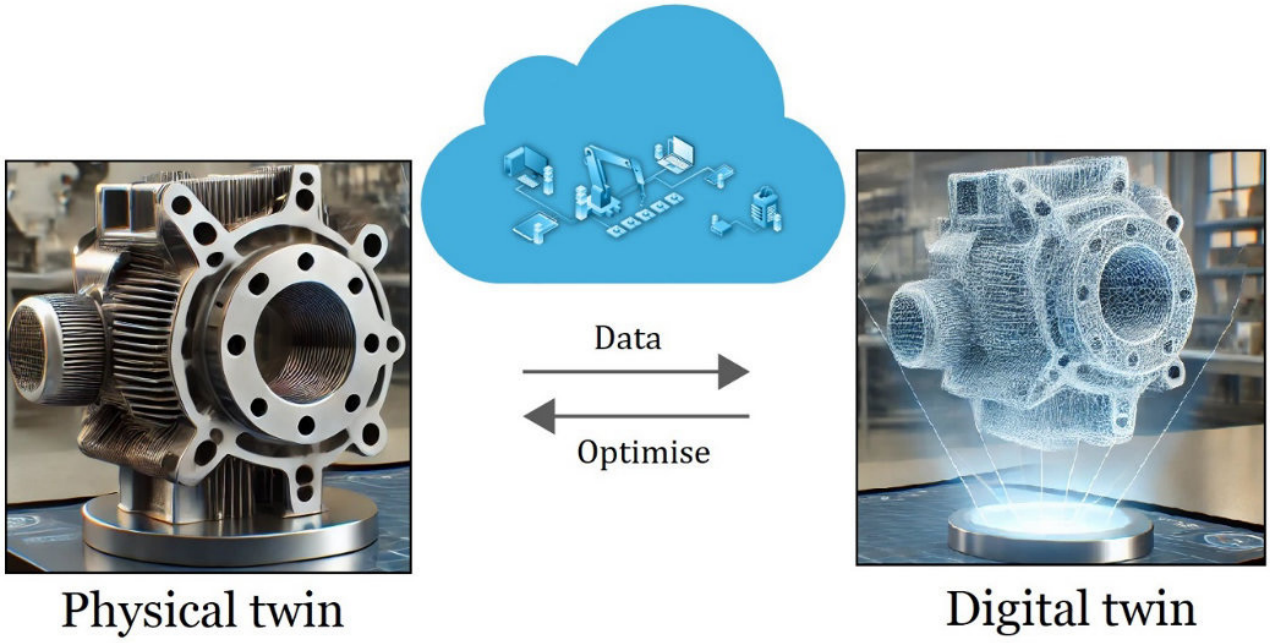
DIGITAL TWINS FOR LASER-BASED METAL ADDITIVE MANUFACTURING



Digital twins concept in Additive Manufacturing

Laser-based metal additive manufacturing (AM) is increasingly used as a versatile method in industrial settings, gradually moving from prototyping applications toward full production. However, controlling the quality of AM products is still challenging, primarily due to their layer-by-layer production approach, which often leads to inconsistencies in material properties and part variability. Additionally, compared to conventionally manufactured parts, typical quality metrics of AM components—such as dimensional accuracy, surface roughness, porosity, and hardness—tend to underperform in the as-built state. Consequently, achieving zero-defect manufacturing, sustainability, and first-time-right production for AM parts remains difficult.

Recently, experts in digital and laser-based manufacturing at the Institute for Advanced Manufacturing and Engineering (AME), Coventry University, joined European partners [1] in an EU Horizon project titled Modular Laser Sources for Sustainable Production of Short Personalised Production Series, or WAVETAILOR [2] to tackle these challenges. This project entails two complex industrial scenarios concerning multi-material components and assemblies. The first scenario focuses on Directed Energy Deposition (DED) to create a multi-material leading edge for a hypersonic, hydrogen-powered aeroplane. The second scenario involves Powder Bed Fusion (PBF) to produce a complex multi-material assembly for a drone designed for urban delivery. WAVETAILOR aims to address challenges in high-precision manufacturing of complex material structures, as well as the disassembly, reuse, and recycling of components, while minimising the environmental footprint of both the manufacturing processes and the components produced.

Given the complexities of laser-material interactions—affected by laser process parameters, material properties, environmental conditions, and part design—a digital twin (DT) in a supervisory role can bring greater certainty to the additive manufacturing process. This is achieved by actively maintaining process parameters within desired bounds through real-time control commands.

The concept of digital twins is integral to the digitalisation of modern production and is widely applied in emerging research focused on real-time sensor data assessment. As noted by Engineering.com [3], digital twins are real-time digital representations that use data analytics and modelling for diagnostics, analysis, and testing of industrial products. In AM, a digital twin assesses the current conditions of the part being produced and can perform corrective actions through integrated feedback loops. With AI-driven predictive capabilities, digital twins can foresee future states of the physical twin (the AM process in this case) by continuously analysing real-time sensor data.

As a research fellow in laser systems data collection at Coventry University, I am pleased to be a part of the WAVETAILOR project and support the development of digital twins for the two important AM use cases. By providing high-quality in-process and post-process data, it is ensured that the DT accurately represents the physical system and enables effective monitoring, simulation, and optimisation of AM processes and products.

Upon achieving WAVETAILOR's objectives, the manufacturing processes for these two use cases are expected to consume 200 MWh less energy, produce 923 kg less waste, and reduce production costs by 50-65%.

[1] WAVETAILOR partners are Joanneum Research, Coventry University, Lortek S Coop, Prima Additive Srl, Nlight Europe Srl, Z Prime Gmbh, Destinus Spain Sl, Aerotecnic Metallic Sl, Morphica Srl, Austrian Energy Agency and Tematys.

[2] https://wavetailor.eu/about/

[3] https://www.engineering.com/striving-toward-the-benefits-of-digital-twins/

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